

Appendix 2.4 B3

Task 2.4 B3: Investigation of Salinity Removal Technologies

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to \$62 mgd to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

1. Buildings End-Use Energy Efficiency
2. Industrial/Agricultural/Water End-Use Energy efficiency
3. Renewable Energy
4. Environmentally-Preferred Advanced Generation
5. Energy-Related Environmental Research
6. Strategic Energy Research

What follows is the final report for *Electrotechnology Applications for Potable Water Production and Protection of the Environment*, Contract No. 500-97-044, conducted by the Metropolitan Water District of Southern California. The report is entitled “Electrotechnology Applications for Potable Water Production and Protection of the Environment: Task 8 Identification of Factors that Influence Fiber Breakage.” This project contributes to the Industrial/Agricultural/Water End-Use Energy Efficiency area.

For more information on the PIER Program, please visit the Commission’s Web site at: <http://www.energy.ca.gov/research/index/html> or contact the Commission’s Publications Unit at 916-654-5200.

Introduction

Background & Overview

The Groundwater Replenishment (GWR) System is a water supply project jointly sponsored by the Orange County Water District (OCWD) and Orange County Sanitation District (OCSD). The GWR System will supplement existing water supplies by providing a new, reliable, high-quality source of water to recharge the Orange County Groundwater Basin (the Basin) and protect the Basin from further degradation due to seawater intrusion. By recycling water, it will also provide peak wastewater flow disposal relief and postpone the need for OCSD to construct a new ocean outfall by diverting treated wastewater flows that would otherwise be discharged to the Pacific Ocean.

The processes used to treat secondary clarified treated wastewater include microfiltration (MF), reverse osmosis (RO), and ultraviolet (UV) disinfection. Part of the scope of OCWD's research under the grant from the California Energy Commission was to investigate salinity removal technologies. In the GWR system, salinity removal occurs in the RO process. Three issues were addressed at OCWD. These included: 1) studying and developing new RO membranes that are resistant to chlorine; 2) investigating nitrification and denitrification of RO brine (waste); and 3) testing the RO and MF processes on the wastewater treatment side.

Project Objectives

As demand for water continues to grow in the western United States and other semi-arid regions throughout the world, developing safe and reliable water from non-traditional sources is becoming ever more attractive. The use of membrane separation processes has been shown to successfully treat a variety of challenging water types from seawater and brackish groundwater to industrial and process wastewaters. The objectives of this research were to study RO membranes' performance using different materials as well as feed sources. Part of research examined treatment methods and options for the brine concentrate generated from the process. Each of the three projects had a different objective.

Chlorine Tolerant Membranes

Project Approach

This project evaluated the performance of a newly developed reverse osmosis (RO) membrane for its ability to treat secondary municipal wastewater.

The development of the polyamide (PA) thin-film composite (TFC) reverse osmosis membrane has successfully enabled water producers to treat a variety of water sources to near distillation quality. Despite the high quality of the water produced by this process, TFC membranes are prone to both colloidal and

biological fouling, which both serve to limit the effectiveness of this treatment process. In treating high biologically active wastewaters, membrane biological fouling (biofouling) is often times one of the most pronounced limitations. Numerous and costly pretreatment measures must be carried out in an effort to limit the onset of membrane biofouling. Chlorine and other disinfectants are commonly introduced into the feedwater to limit the occurrence of biological fouling. While this practice is generally effective, it can result in degradation of TFC membranes, which are susceptible to chemical attack by strong oxidizing agents such as chlorine.

The performance of a chemically tolerant, low-fouling reverse osmosis (RO) membrane was evaluated at the Orange County Water District (OCWD) for its ability to treat clarified secondary municipal wastewater effluent. Testing of the CPTC membrane was conducted using two different plant feedwaters produced at OCWD: Water Factory 21 and Green Acres Project (GAP). Membrane performance was compared to that of commercially available TFC membranes.

Project Outcomes

After running the developed membranes in a flat sheet membrane test unit, results were compared and correlated with computer modeling results.

Membrane performance of the new membrane was found to be equal, or superior to traditional commercial RO membranes operated simultaneously at OCWD. Water quality was comparable while the total product water production was generally greater than the commercial membranes. The rate at which water production (or flux) declined was also generally lower than the commercial membranes.

It has been successfully shown that membrane separation processes can successfully treat a variety of challenging water types. Commercial TFC membranes in the marketplace lack chemical tolerance to such oxidants as chlorine. A chemically tolerant, low-fouling TFC membrane could quickly expand in the current membrane environment.

Brine Disposal

Project Approach

Recycled water has become one of the significant resources used to replenish the existing water bodies, especially in the states where the production of sufficient water of high quality cannot meet the demand of growing population. Among the technologies employed to obtain recycled water are membrane processes such as microfiltration, ultrafiltration, and reverse osmosis. Recycled water passed through a reverse osmosis membrane is considered highly pure and safe for use.

It is important to determine the disposal or treatment strategies for such brines ahead of time during the planning stage of a membrane purification plant, as it may become a problematic issue later.

Fluidized Bed Biofilm Reactors charged with Granular Activated Carbon (FBBR-GAC) were chosen as a promising technology for the nitrification and denitrification of reverse osmosis brine concentrates to remove nitrates and sulfates. This research would also create a model to describe the process dynamics and implement inexpensive pilot-scale testing. Several batch experiments were conducted to find the optimum environmental parameters for the highest possible removal efficiency. Additionally, a series of experiments were conducted to predict the denitrification efficiency of the FBBR-GAC column and to verify the model.

Project Outcomes

The FBBR-GAC system has proven very efficient both in terms of process and energy consumption for the denitrification and sulfate reduction of brine concentrates. The optimum operating parameters were determined in this research. Most importantly, preliminary laboratory-scale experiments revealed that the FBBR-GAC process is capable of removing approximately 45% of sulfate and 100% nitrate.

IMANS™

Project Approach

The GWR System will treat secondary wastewater effluent, currently discharged to the ocean, to produce high-quality water for recharge of the Orange County groundwater basin and injection into a seawater intrusion barrier.

Phase 1 of the GWR project is presently in the preliminary design stage and is due to be operational in 2003. Phase 1 will produce 70 mgd of high quality, low salinity product water, while the three-phase GWR project will ultimately produce about 150 mgd of high quality reclaimed water by 2020.

The Phase 1 treatment system will adopt the current state-of-the-art approach to wastewater reclamation. This includes full secondary wastewater treatment, followed by MF, RO, and UV disinfection to produce high-quality water. There will also be a final UV disinfection step.

Phases 2 and 3 of the GWR project have not yet been defined, and they present a number of different challenges including:

1. a shortage of land,
2. high costs associated with additional secondary wastewater treatment facilities, and
3. costs associated with the disposal of large quantities of biosolids.

This report summarizes the novel treatment approach, the pilot processes tested, and the results obtained from the pilot testing. Also presented is a cost estimate and a comparison for full-scale facilities based on the IMANS™ approach and the current conventional state-of-the-art approach to water reclamation. A section of the report also provides conceptual information on the possible approach of

using the MF product water from the IMANS™ system for direct discharge to the 78-inch ocean outfall.

The purpose of the preliminary evaluation of the IMANS™ process is two-fold:

1. To determine the technical feasibility of operating the new process combination to treat primary effluent to produce a high quality re-usable water suitable for ground water injection and recharge, and,
2. To evaluate and compare the cost-effectiveness of the IMANS™ approach with the state-of-the-art process combination that includes full secondary wastewater treatment followed by MF and RO.

Project Outcomes

The initial testing of the IMANS™ process approach for wastewater treatment combined with water reclamation has shown promising results in terms of both sustainable performance and cost effectiveness. Potential capital cost savings and significant O&M cost savings are predicted for an IMANS™ approach compared with the conventional approach of using membranes to treat secondary wastewater effluent. This has established the technical feasibility of the IMANS™ process combination, even under challenging test conditions such as use of a six-year-old MF pilot.

Conclusions & Recommendations

Chlorine Tolerant Membranes

Conclusions

Long-term performance of the CPTC membrane was equal, or superior to traditional commercial membranes. While still in its adolescence, the CPTC membrane looks promising as a membrane that could successfully treat high fouling water sources without compromising membrane integrity and performance due to fouling and chemical degradation.

Commercialization Potential

Membrane treatment technologies are continually expanding as locations within the United States and around the world are witnessing substantial population growth rates and corresponding increases in water demand. This is particularly evident when noting the expansion of the membrane technology market, which is estimated to have increased from \$363 million in 1987 to more than \$1 billion in 1997.

Commercial TFC polyamide RO membranes in the marketplace lack the chemical stability to oxidants such as chlorine. A chemically tolerant TFC membrane could quickly expand in the marketplace since most treatment facilities already operate TFC polyamide membranes.

Recommendations

The successful development and widespread implementation of a new polymer membrane is a timely process. Since the CPTC membrane is still in its adolescence, more testing would be required to determine the practicability of this membrane as an alternative to conventional TFC membranes in treating high fouling water and wastewater sources.

Benefits To California

As the population continues to increase in Southern California (and other areas in the California), water agencies will have to address the issue of increasing water demand. In Orange County, the population is estimated to increase to more than 3 million in the next 20 years. Reliable, safe and cost-effective sources of potable water must be developed to sustain population growth in Southern California. Developing non-traditional water sources for potable purposes require advanced water treatment facilities, which ultimately include membrane processes. The use of highly efficient, low fouling membranes would ultimately increase product water throughput while minimizing associated treatment costs.

TFC polyamide membranes operate at lower operating pressures than cellulose acetate membranes, which can translate into significant energy savings of 30% to 40%. Using a lower pressure TFC membrane that exhibits fouling resistance would further reduce energy costs as well. Less biofilm proliferation and accumulation on the membrane surface would result in lower operating pressures and subsequently lower energy costs. An increase in feed pressure of 25psi due to membrane biofouling is estimated to result in an increase of \$7000 (500gpm, 75% pump efficiency) at \$0.10/KWH (Dow Chemical, 1999). Minimizing the occurrence of membrane biofouling through the use lower fouling, more efficient TFC membranes could ultimately result in significant energy savings for the California water producer already faced with looming power concerns.

Brine Disposal

Conclusions

The optimum temperature range for the denitrification was determined to be between 20°C and 40°C. The total dissolved solid (TDS) concentration had insignificant effect on the denitrification rate. Preliminary laboratory-scale experiments revealed that the FBBR-GAC process is capable of removing approximately 45% of sulfate and 100% nitrate.

Commercialization Potential

A predictive model was developed for performance forecasting and up-scaling of the FBBR-GAC process. The preliminary modeling simulation/prediction results are encouraging. Nonetheless, more studies are underway to upgrade the model.

Recommendations

It is recommended that the FBBR-GAC process be further investigated in laboratory scale as well as in pilot scale in order to assess its energy efficiency and cost-effectiveness. Sulfate reduction is an additional advantage of the FBBR-GAC system described above. However, more investigation is needed in order to upgrade the system for better sulfate removal. Additionally, a model may be developed for the biological removal in dual-substrate systems (in this case, nitrate and sulfate). Furthermore, detailed experimentation is needed to formulate a model that predicts simultaneous nitrate and sulfate removal in such systems.

Benefits To California

As mentioned in the introduction section, water recycling is foreseen as one of the best alternatives to meet the ever-increasing water demand. It is through recycled water that the depleted groundwaters are replenished, saline water intrusion from the ocean is prevented, and surface waters are augmented. California is one of the states that will suffer severely from polluted or depleted water resources in the near future. Currently, water demand in Southern California is being met by imported water from the northern region and from the Colorado River Project. This method of supply is highly expensive and not reliable from a long-term perspective. Therefore, the Orange County Water District, one of the leading research utilities in the US, is currently involved in extensive research on water recycling and groundwater replenishment.

The Fluidized Bed Biofilm Reactor with Granular Activated Carbon technology that has been introduced and discussed in this report has been proven to be very effective in the treatment of the RO brine concentrates. It is capable of removing nitrates completely sulfates partly from the brine waste streams. Furthermore, it is conceivable to upgrade the FBBR-GAC system to achieve sulfate reduction. One notable advantage of fluidized bed reactors is that they require minimal space, and the reactor size is relatively smaller as compared to conventional techniques due to excessive biomass growth. The reaction time is short and the treatment efficiency is high, making it easily adoptable by the utilities planning to employ the RO technology to recycle water, in residential areas where land availability is scarce or limited.

IMANS™

Conclusions

The initial testing of the IMANS™ process approach for wastewater treatment combined with water reclamation has shown promising results in terms of both sustainable performance and cost effectiveness. Potential capital cost savings and significant O&M cost savings are predicted for an IMANS™ approach compared with the conventional approach of using membranes to treat secondary wastewater effluent. This has established the technical feasibility of the IMANS™ process combination, even under challenging test conditions such as use of a six-year-old MF pilot.

Elimination of the secondary wastewater treatment step, lower life cycle costs, 50 percent less solids production, and smaller plant footprint, all establish the potential benefits of this new approach to wastewater treatment and reclamation using membrane filtration on primary wastewater effluent.

Commercialization Potential

This system could be applied to wastewater treatment plants to address flow relief. By stressing the membranes and producing the same high water quality, the idea of recycling water and management of wastewater discharge combines into one project.

Recommendations

It is necessary to study how other configurations of MF units could treat primary effluent. It will also be important to create dialogue between the regulatory agencies to discuss possible alternatives for reuse and discharge.

Benefits To California

This research and demonstration testing could significantly alter the manner in which wastewater agencies discharge into the ocean or any other water body. By evaluating the microfiltration process as a means of disposing primary effluent, alternate methods can help better manage waste discharges.